



US009377329B2

(12) **United States Patent**  
**Kueckendahl et al.**

(10) **Patent No.:** **US 9,377,329 B2**  
(45) **Date of Patent:** **Jun. 28, 2016**

(54) **SENSOR APPARATUS**

(75) Inventors: **Peter Joerg Kueckendahl**, Bad Oldesloe (DE); **Daniel Joseph Ryan**, Sycamore, IL (US)

(73) Assignee: **ALLTEC Angewandte Laserlicht Technologie GmbH**, Selmsdorf (DE)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 367 days.

(21) Appl. No.: **13/976,820**

(22) PCT Filed: **Dec. 22, 2011**

(86) PCT No.: **PCT/EP2011/006515**  
§ 371 (c)(1),  
(2), (4) Date: **Jun. 27, 2013**

(87) PCT Pub. No.: **WO2012/089320**  
PCT Pub. Date: **Jul. 5, 2012**

(65) **Prior Publication Data**  
US 2013/0305848 A1 Nov. 21, 2013

(30) **Foreign Application Priority Data**  
Dec. 30, 2010 (EP) ..... 10016196

(51) **Int. Cl.**  
**G01N 11/00** (2006.01)  
**G01D 11/00** (2006.01)  
**H04N 1/193** (2006.01)  
**H04N 1/195** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **G01D 11/00** (2013.01); **H04N 1/193** (2013.01); **H04N 1/1932** (2013.01); **H04N 1/19505** (2013.01); **H04N 1/19573** (2013.01)

(58) **Field of Classification Search**  
None  
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,707,063 A 11/1987 Plummer  
4,884,974 A \* 12/1989 DeSmet ..... 434/317  
5,152,962 A \* 10/1992 Lackie ..... 422/68.1

(Continued)

FOREIGN PATENT DOCUMENTS

DE 2401322 1/1974  
DE 3826113 A1 2/1989

(Continued)

OTHER PUBLICATIONS

Notice of Allowance and Fee(s) due for U.S. Appl. No. 13/976,809, dated Jul. 7, 2015, 17 pages.

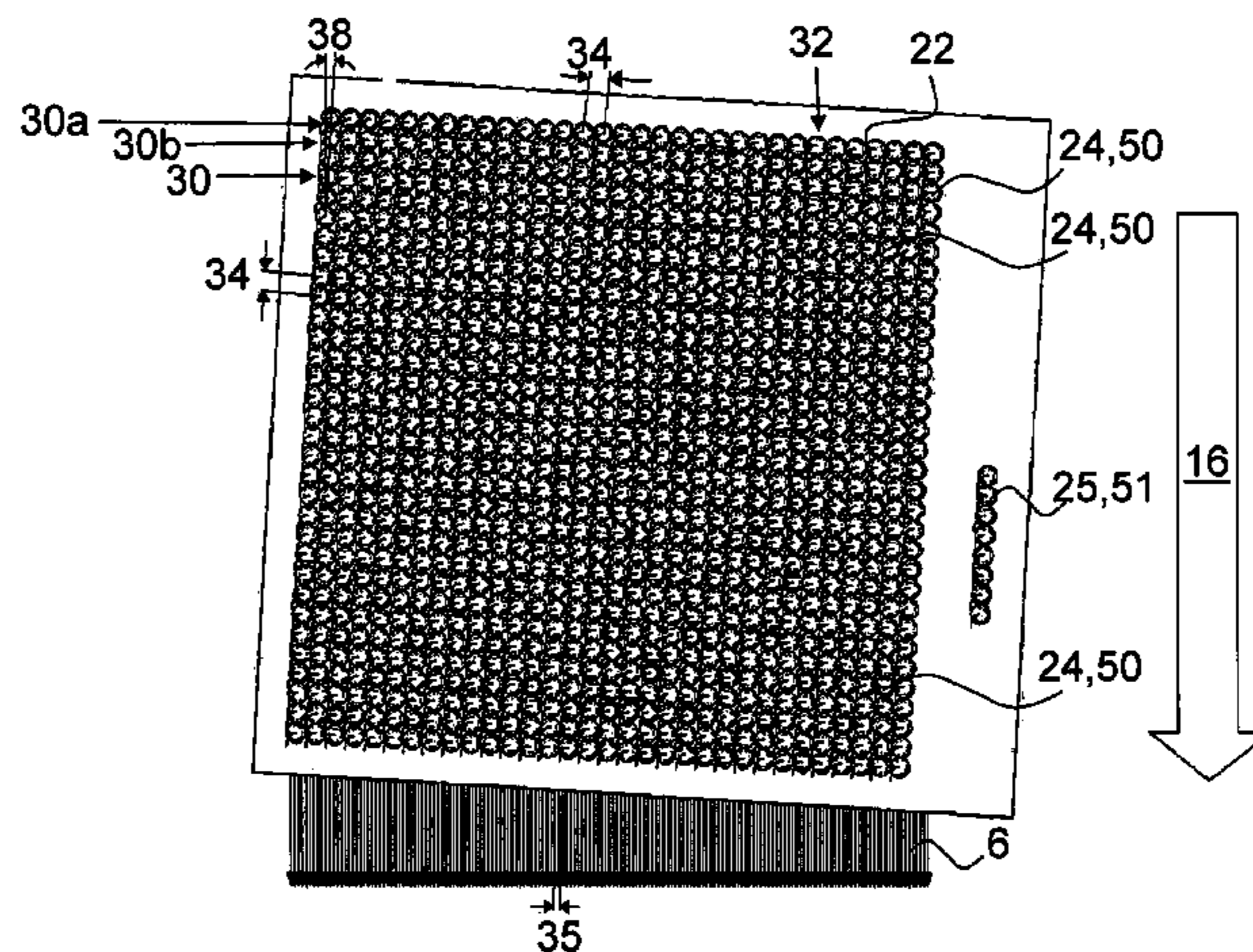
(Continued)

*Primary Examiner* — Robert R Raevis  
(74) *Attorney, Agent, or Firm* — Hoffman Warnick LLC

(57) **ABSTRACT**

The invention relates to a sensor apparatus for detecting an object comprising a sensor head having a plurality of receiving spaces for individual sensor devices and a driving mechanism for providing a relative movement of the object relative to the sensor head in an advance direction during a detecting operation. The receiving spaces are arranged in a plurality of rows and columns, such that an array of receiving spaces with a rectangular pattern of the receiving spaces is formed, and the array of receiving spaces is tilted with regard to the advance direction such that the rows extend in a transverse direction relative to the advance direction and the receiving spaces of a successive row of the rectangular pattern are offset with regard to the receiving spaces of a preceding row of the rectangular pattern in a direction perpendicular to the advance direction.

**15 Claims, 15 Drawing Sheets**



(56)

References Cited

OTHER PUBLICATIONS

U.S. PATENT DOCUMENTS

5,399,032	A	3/1995	Itoh et al.	
5,477,259	A	12/1995	Iwasa	
5,777,634	A	7/1998	Okamura et al.	
5,784,098	A	7/1998	Shoji et al.	
5,797,845	A *	8/1998	Barabash et al.	600/443
6,189,991	B1	2/2001	Wen et al.	
6,286,927	B1	9/2001	Taneya et al.	
6,381,377	B1 *	4/2002	Wang	382/299
6,469,729	B1	10/2002	Ryan	
6,738,086	B2	5/2004	Oka	
6,855,921	B1	2/2005	Stopperan et al.	
7,354,130	B2	4/2008	Arakawa	
7,443,508	B1 *	10/2008	Vrhel et al.	356/446
7,448,719	B1	11/2008	Newell	
7,564,020	B2	7/2009	Sergyeyenko	
7,671,337	B1	3/2010	Tidwell	
7,908,968	B2	3/2011	McCoin et al.	
2002/0001004	A1	1/2002	Mantell et al.	
2002/0101469	A1	8/2002	Wade et al.	
2002/0109741	A1	8/2002	Okabe et al.	
2002/0139273	A1	10/2002	Murata et al.	
2002/0140801	A1 *	10/2002	Kubota	347/239
2002/0191069	A1	12/2002	Oka	
2003/0016348	A1	1/2003	Sallee	
2003/0210861	A1	11/2003	Weiss et al.	
2003/0235373	A1	12/2003	Ishii et al.	
2004/0160478	A1	8/2004	Weijkamp et al.	
2005/0122548	A1 *	6/2005	Cunnigan et al.	358/494
2005/0123303	A1	6/2005	Guttman et al.	
2005/0140770	A1	6/2005	Kang et al.	
2005/0226466	A1 *	10/2005	Seymour	382/112
2005/0286093	A1	12/2005	Sumi et al.	
2006/0006486	A1 *	1/2006	Seo et al.	257/433
2006/0066924	A1	3/2006	Delueg	
2006/0109525	A1	5/2006	Evans	
2007/0091132	A1	4/2007	Lim	
2007/0279713	A1	12/2007	Feng et al.	
2008/0055352	A1	3/2008	Toh et al.	
2008/0246962	A1	10/2008	Yang	
2009/0032714	A1 *	2/2009	Peter et al.	250/363.01
2009/0220199	A1 *	9/2009	Yazaki et al.	385/78
2010/0002057	A1	1/2010	Hatasa et al.	
2010/0102032	A1	4/2010	Bathelet	
2010/0214387	A1	8/2010	Fox et al.	
2010/0231929	A1 *	9/2010	Kakigi	358/1.2
2013/0021398	A1	1/2013	Mizes et al.	
2013/0286147	A1	10/2013	Kueckendahl et al.	
2013/0286148	A1	10/2013	Kueckendahl et al.	
2013/0286149	A1	10/2013	Kueckendahl et al.	
2013/0293658	A1	11/2013	Kueckendahl et al.	
2013/0328978	A1	12/2013	Sekino et al.	
2013/0342823	A1	12/2013	Kueckendahl et al.	

FOREIGN PATENT DOCUMENTS

EP	0121369	A2	10/1984
EP	0832754	B1	12/1993
EP	0832752	A2	4/1998
EP	1266763	A1	12/2002
EP	1640169	A3	9/2005
EP	1640169	A2	3/2006
EP	1640169	A3	10/2007
EP	2105309	A1	9/2009
JP	59136267		8/1984
JP	05185686		7/1993
JP	2001332806	A	11/2001
JP	2007090814	A	4/2007
JP	2008126471	A	6/2008
JP	2009037128	A	2/2009
WO	8505187	A1	11/1985
WO	2006037973	A1	4/2006
WO	2007107030	A1	9/2007
WO	2008104222	A1	9/2008
WO	2009153795	A1	12/2009

Notice of Allowance and Fee(s) due for U.S. Appl. No. 13/977,151, dated Jul. 29, 2015, 18 pages.

U.S. Appl. No. 13/976,804, Notice of Allowance, Feb. 3, 2015, 11 pages.

U.S. Appl. No. 13/976,793, Notice of Allowance, Feb. 4, 2015, 16 pages.

U.S. Appl. No. 13/976,779, Notice of Allowance, Feb. 6, 2015, 18 pages.

U.S. Appl. No. 13/976,809, Office Action, Feb. 6, 2015, 78 pages.

U.S. Appl. No. 13/977,151, Office Action, Feb. 17, 2015, 70 pages.

U.S. Appl. No. 13/977,159, Notice of Allowance, Feb. 17, 2015, 15 pages.

U.S. Appl. No. 13/977,156, Notice of Allowance dated Mar. 16, 2015, 21 pgs.

International Application No. PCT/EP2011/006515, International Preliminary Report on Patentability, Jan. 21, 2013.

International Application No. PCT/EP2011/006515, Written Opinion on Search Report.

International Application No. PCT/EP2011/006518, Written Opinion of International Search Authority.

International Application No. PCT/EP2011/006519, Written Opinion of International Search Authority.

International Application No. PCT/EP2011/006519, Preliminary Report on Patentability.

International Application No. PCT/EP2011/006517, Written Opinion of International Search Authority.

U.S. Appl. No. 13/976,832, Notice of Allowance dated Oct. 8, 2014, 61 pages.

U.S. Appl. No. 13/976,814, Notice of Allowance dated Oct. 21, 2014, 72 pages.

U.S. Appl. No. 13/976,804, Final Office Action dated Oct. 24, 2014, pp. 18.

U.S. Appl. No. 13/977,159, Final Office Action dated Oct. 10, 2014, 53 pages.

U.S. Appl. No. 13/977,156, Final Office Action dated Dec. 5, 2014, 13 pages.

U.S. Appl. No. 13/976,793, Notice of Allowance dated Dec. 9, 2014, 66 pages.

U.S. Appl. No. 13/976,779, Notice of Allowance dated Oct. 21, 2014, 34 pages.

U.S. Appl. No. 13/976,779, Office Action dated Jun. 16, 2014.

U.S. Appl. No. 13/976,804, Notice of Allowance dated Mar. 20, 2014.

U.S. Appl. No. 13/976,809, Office Action dated May 27, 2014.

U.S. Appl. No. 13/977,159, Office Action dated Jun. 20, 2014.

U.S. Appl. No. 13/976,832, Notice of Allowance and Fees Due dated Jun. 24, 2014.

International Application No. PCT/EP2011/006516, Written Opinion of International Search Authority.

U.S. Appl. No. 13/976,814, Notice of Allowance Dated Dec. 29, 2014, 10 pages.

International Application No. PCT/EP2011/006520, Written Opinion of International Search Authority.

International Application No. PCT/EP2011/006514, Written Opinion of International Search Authority.

International Application No. PCT/EP2011/006522, Written Opinion of International Search Authority.

International Application No. PCT/EP2011/006522, International Report on Patentability.

International Application No. PCT/EP2011/00652023, Written Opinion of International Search Authority.

International Application No. PCT/EP2011/006521, Written Opinion of International Search Authority.

International Application No. PCT/EP2011/006521, Written Opinion of International Examining Authority.

U.S. Appl. No. 13/976,804, Office Action dated Jul. 8, 2014.

U.S. Appl. No. 13/976,793, Office Action dated Jul. 1, 2014.

U.S. Appl. No. 13/977,151, Notice of Allowance and Fees Due dated Aug. 4, 2014.

U.S. Appl. No. 13/977,156, Office Action dated Jul. 9, 2014.

U.S. Appl. No. 13/976,804, Notice of Allowance dated Apr. 30, 2015, 55 pgs.

International Application No. PCT/EP2011/006516, International Search Report, dated Mar. 23, 2012, 3 pages.

\* cited by examiner

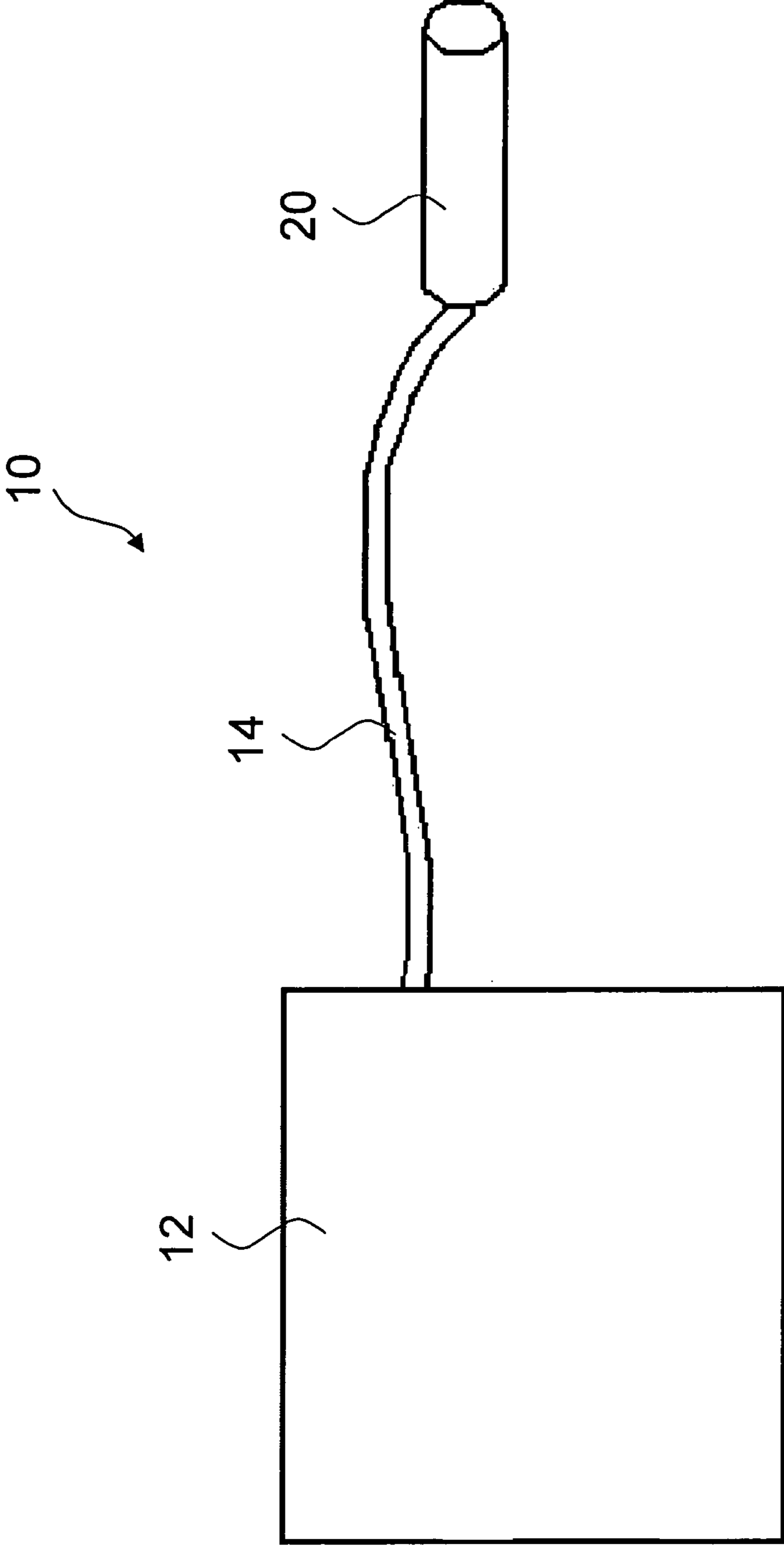


Fig. 1

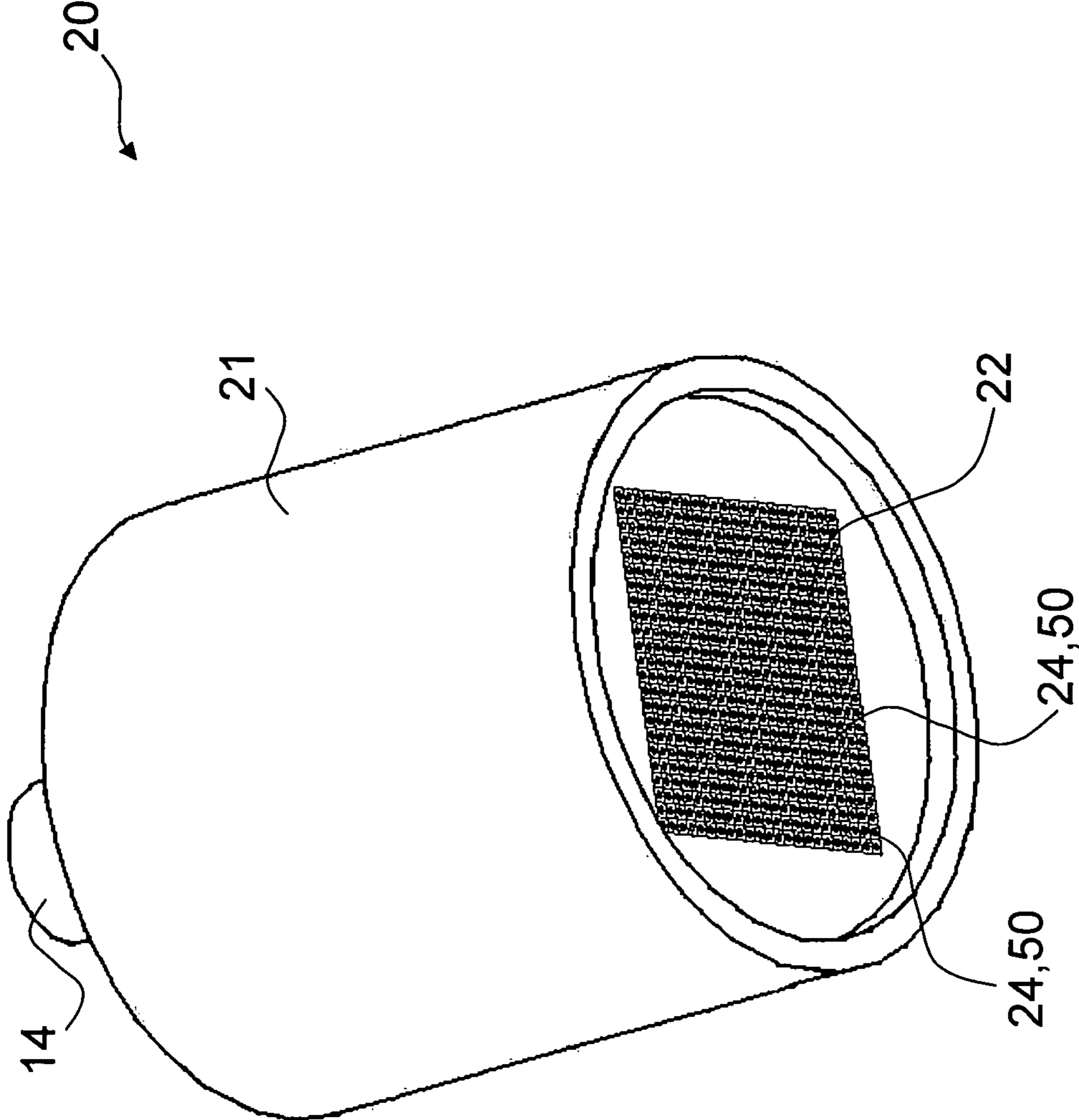


Fig. 2

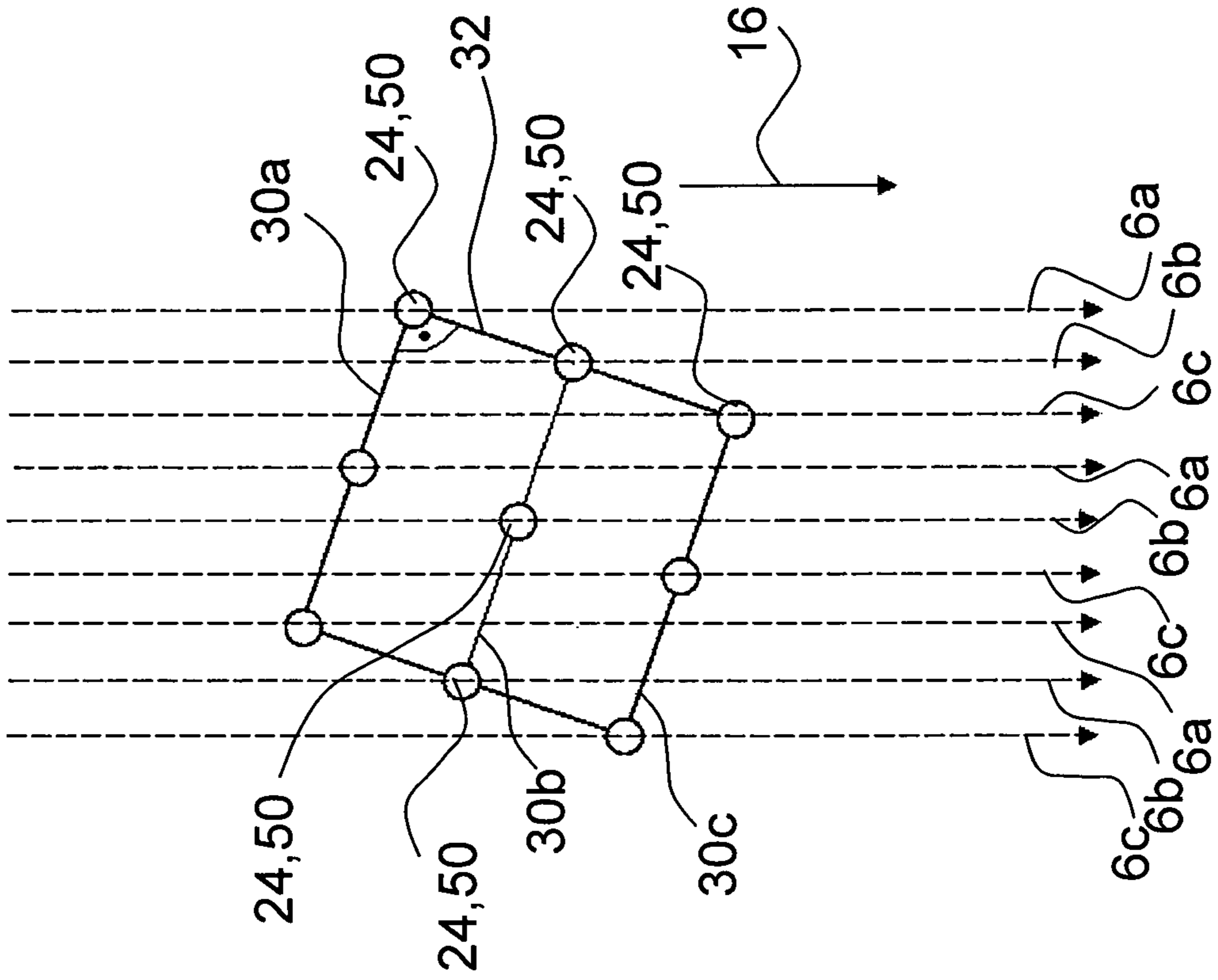


Fig. 3

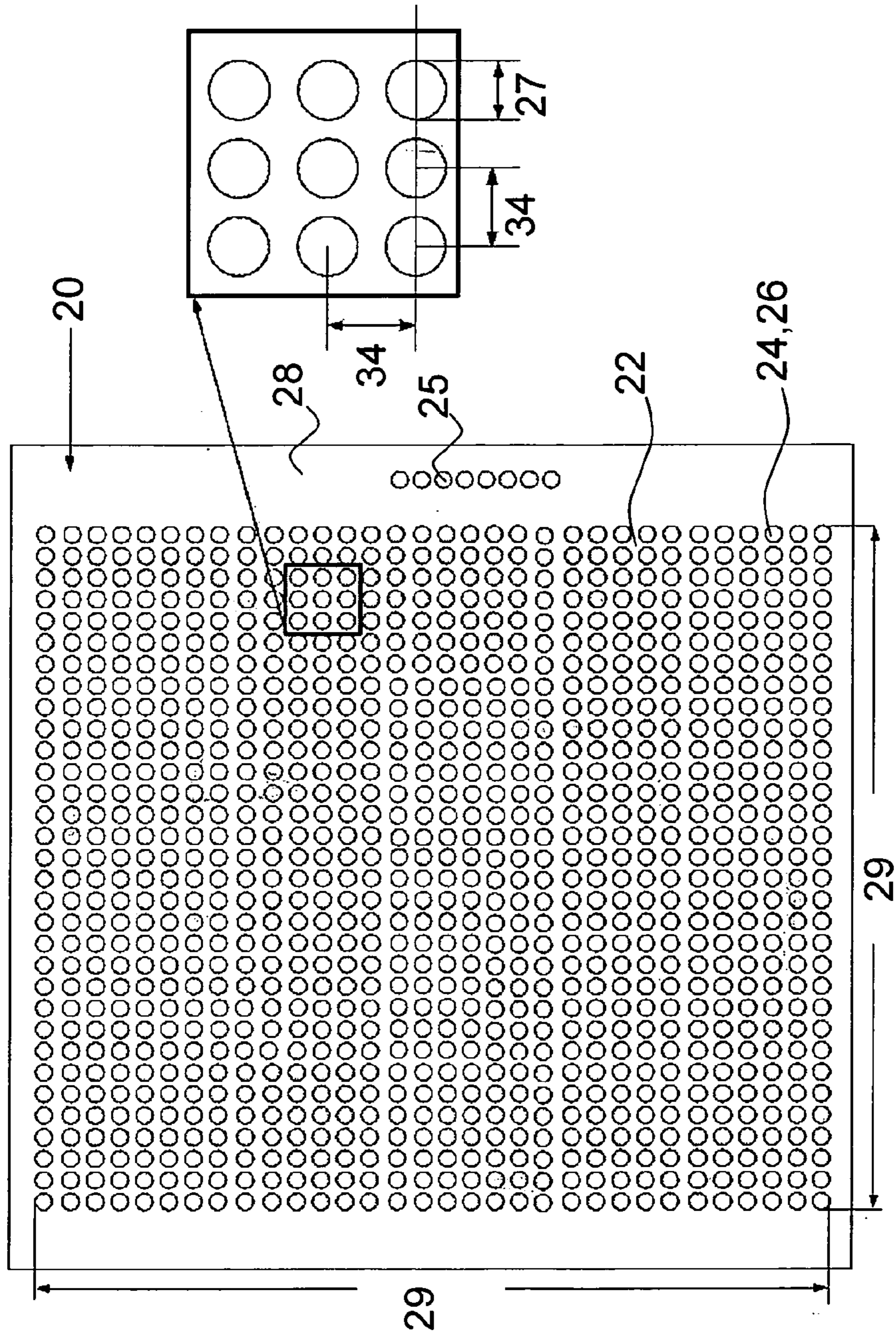


Fig. 4

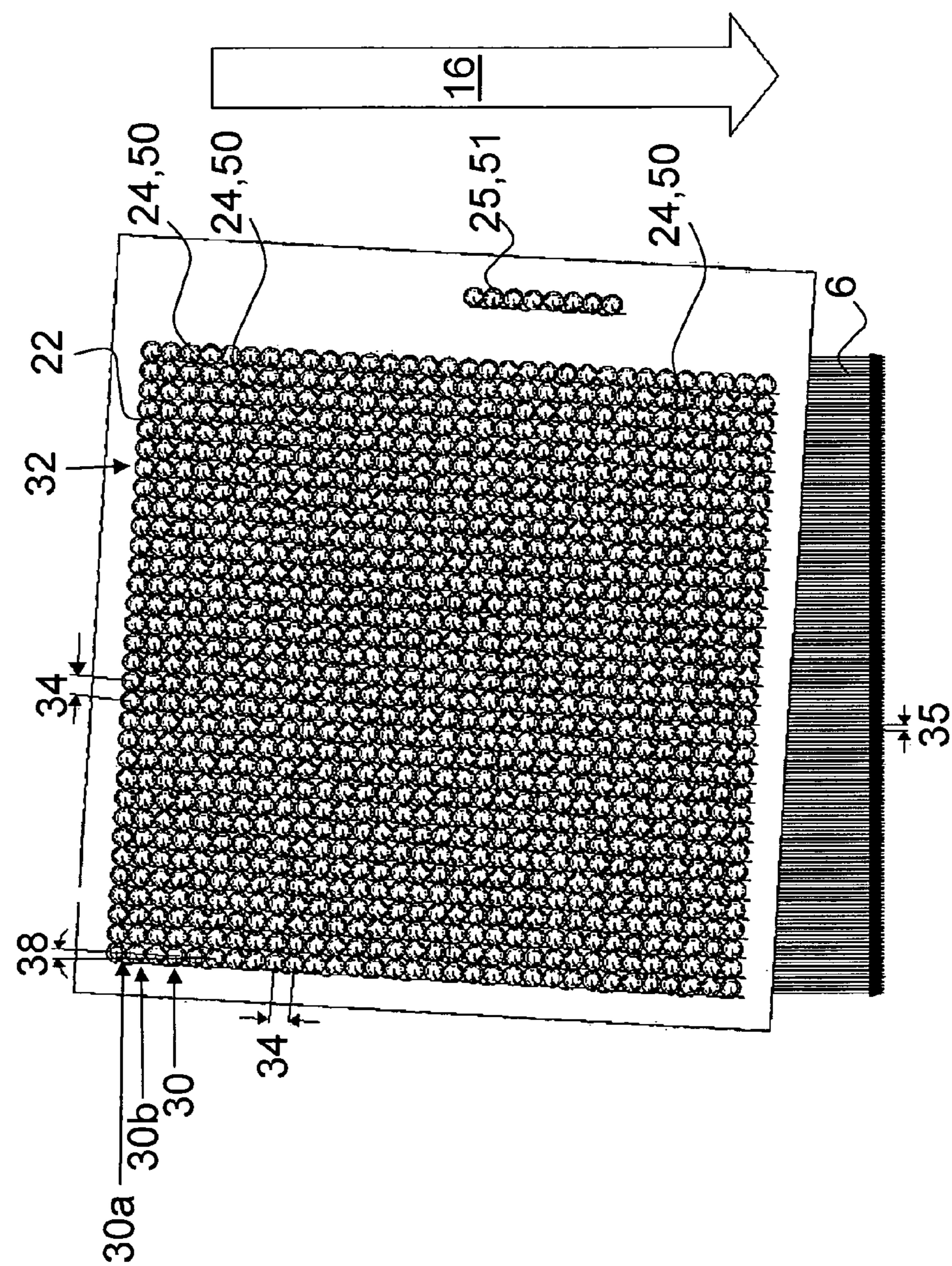


Fig. 5

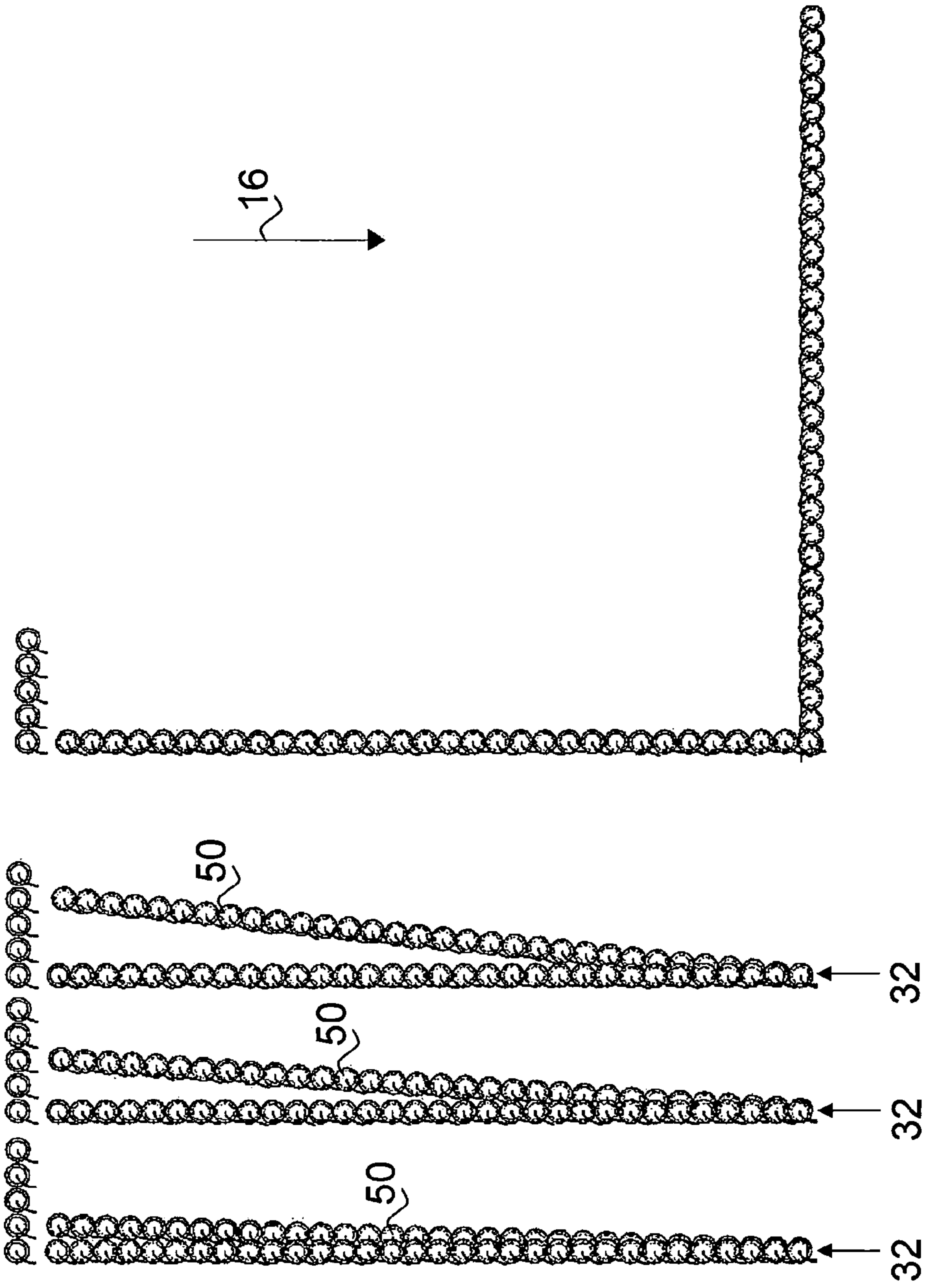


Fig. 6



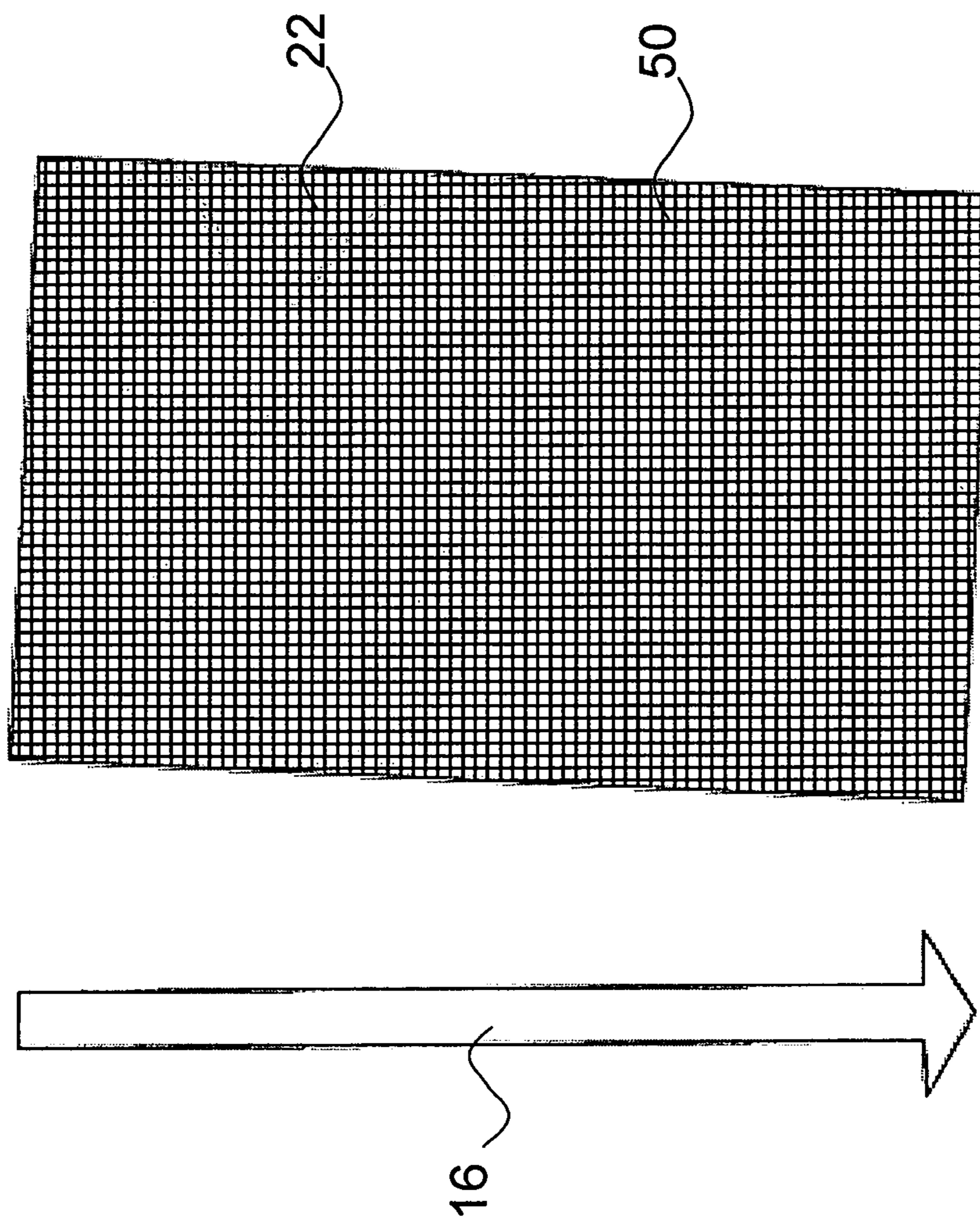


Fig. 7

Fig. 8

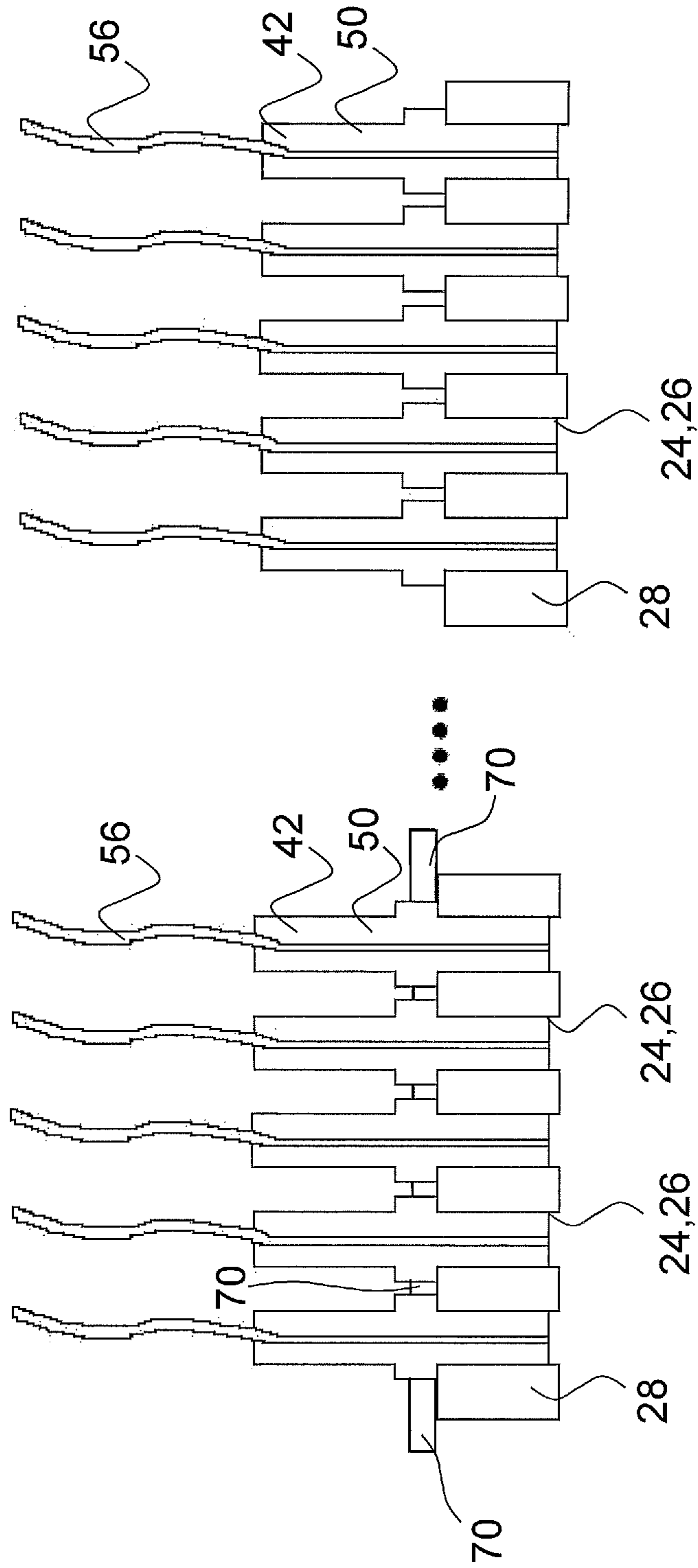
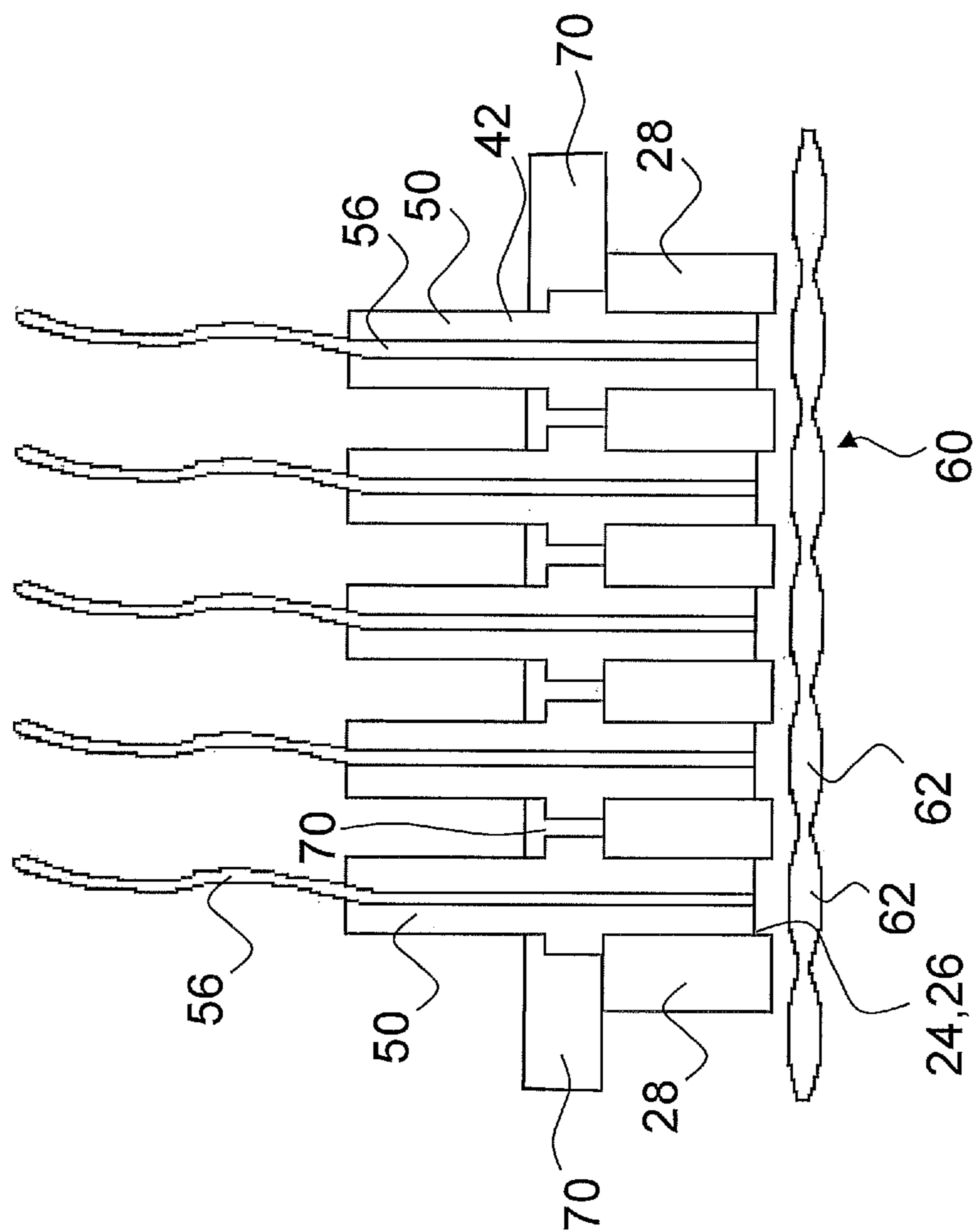


Fig. 9



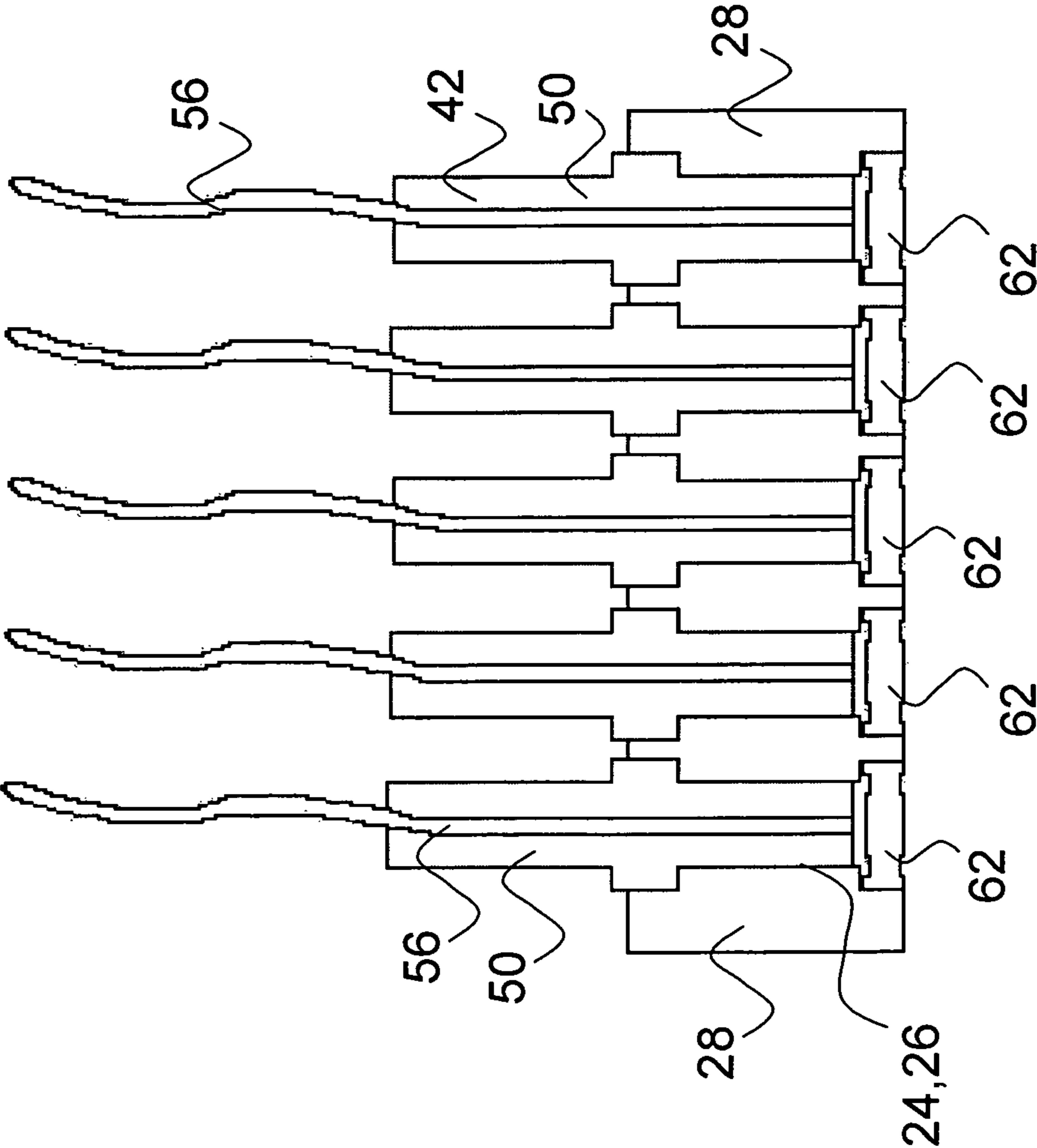


Fig. 10

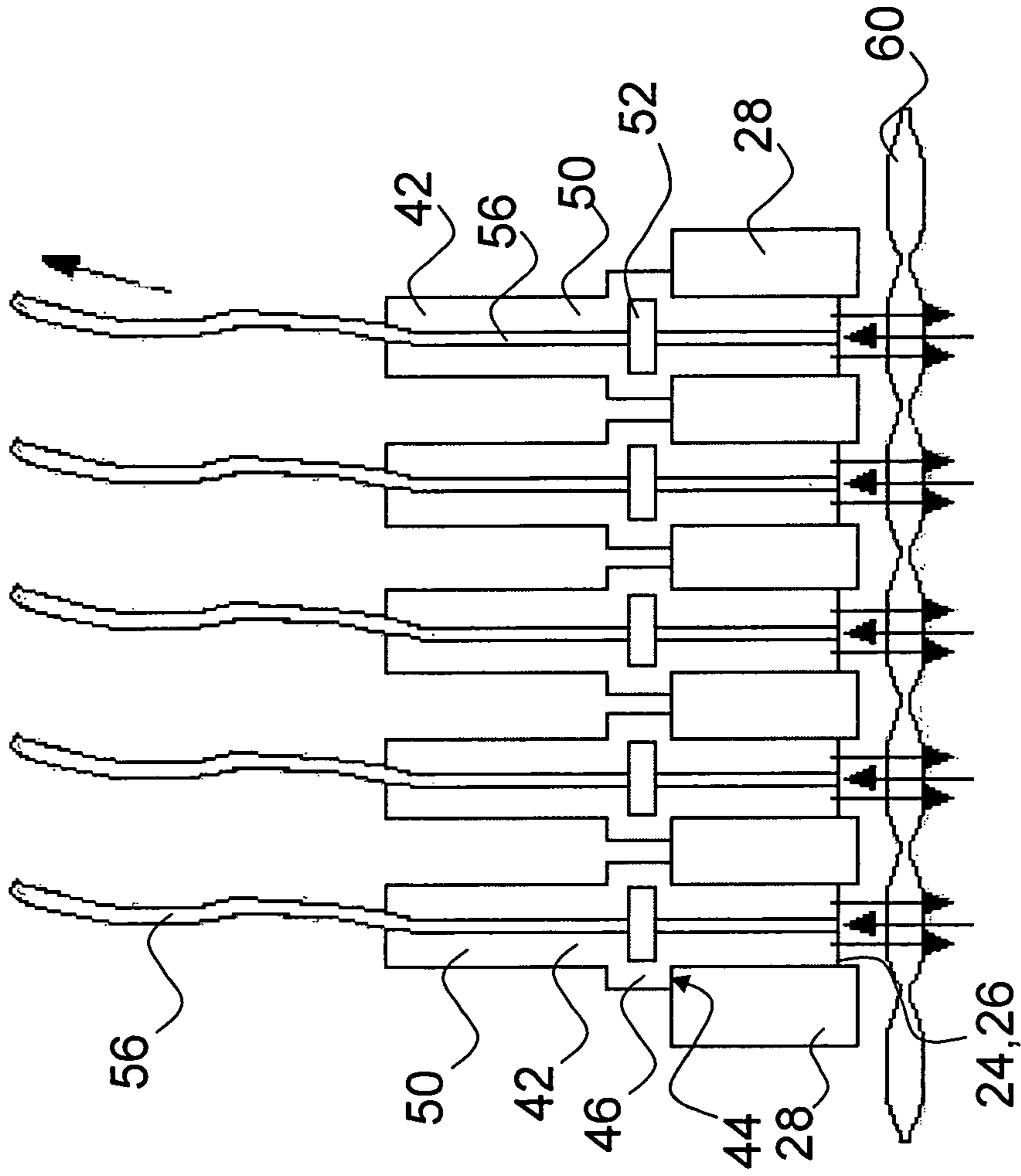


Fig. 11

Fig. 12

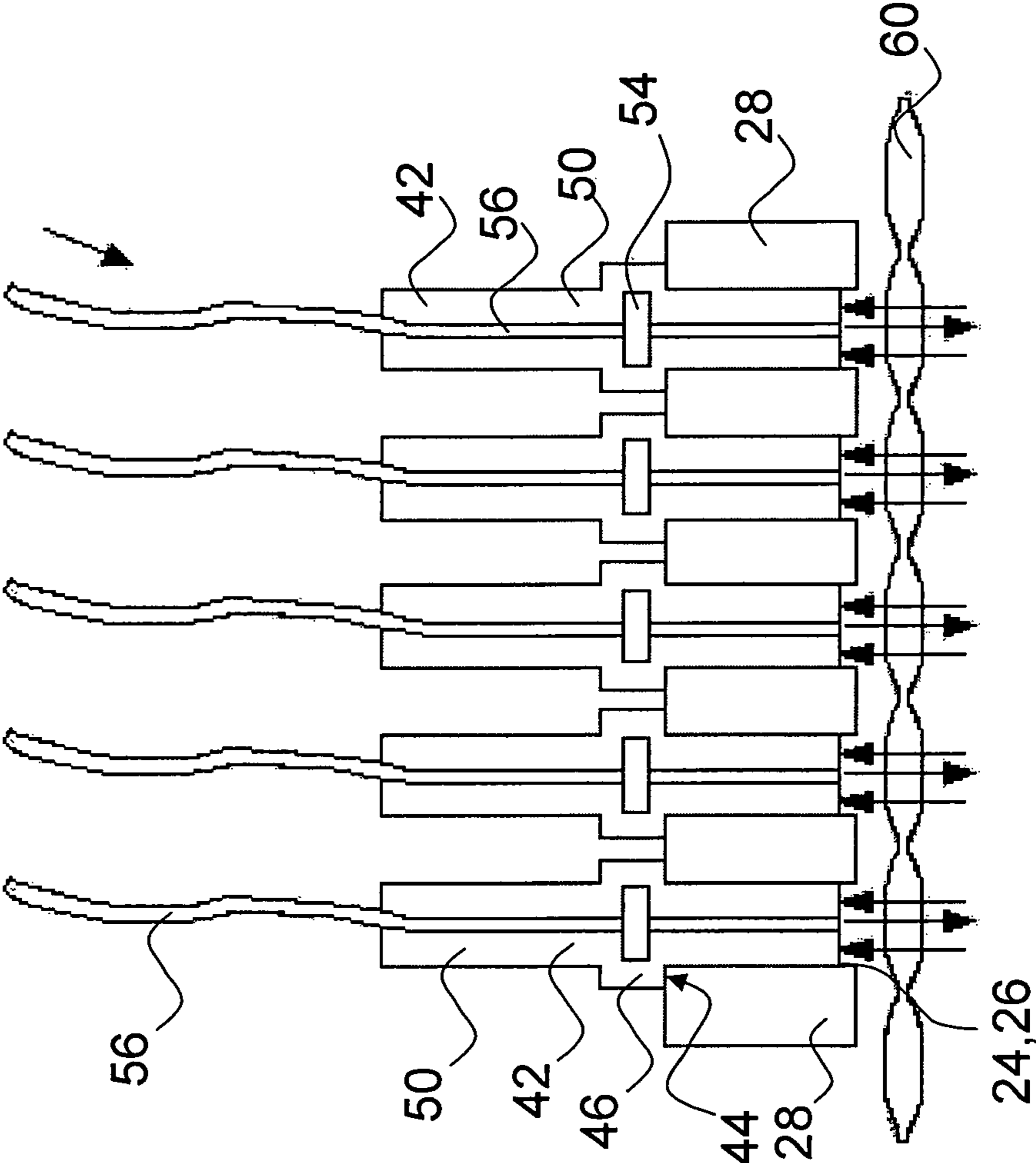
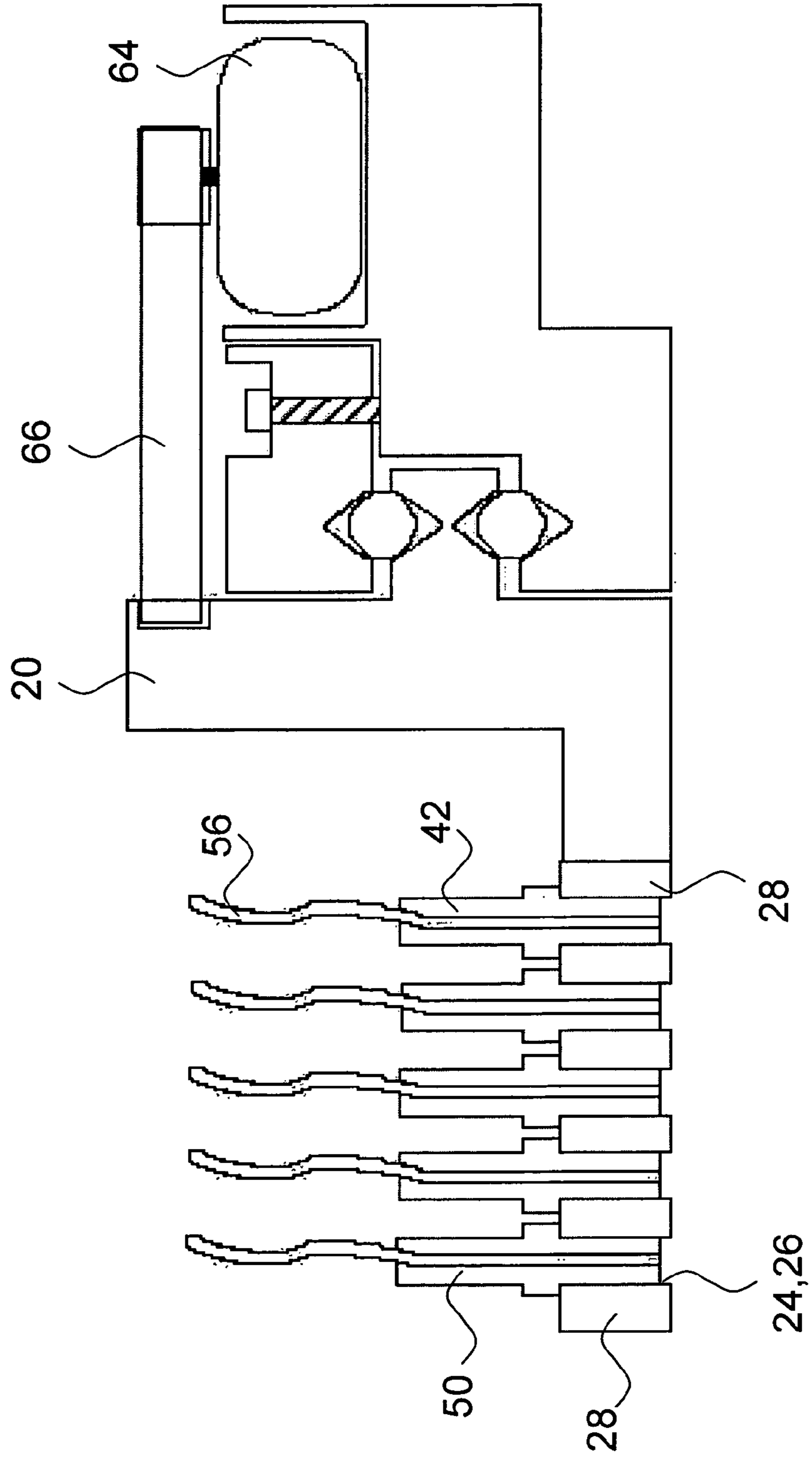


Fig. 13



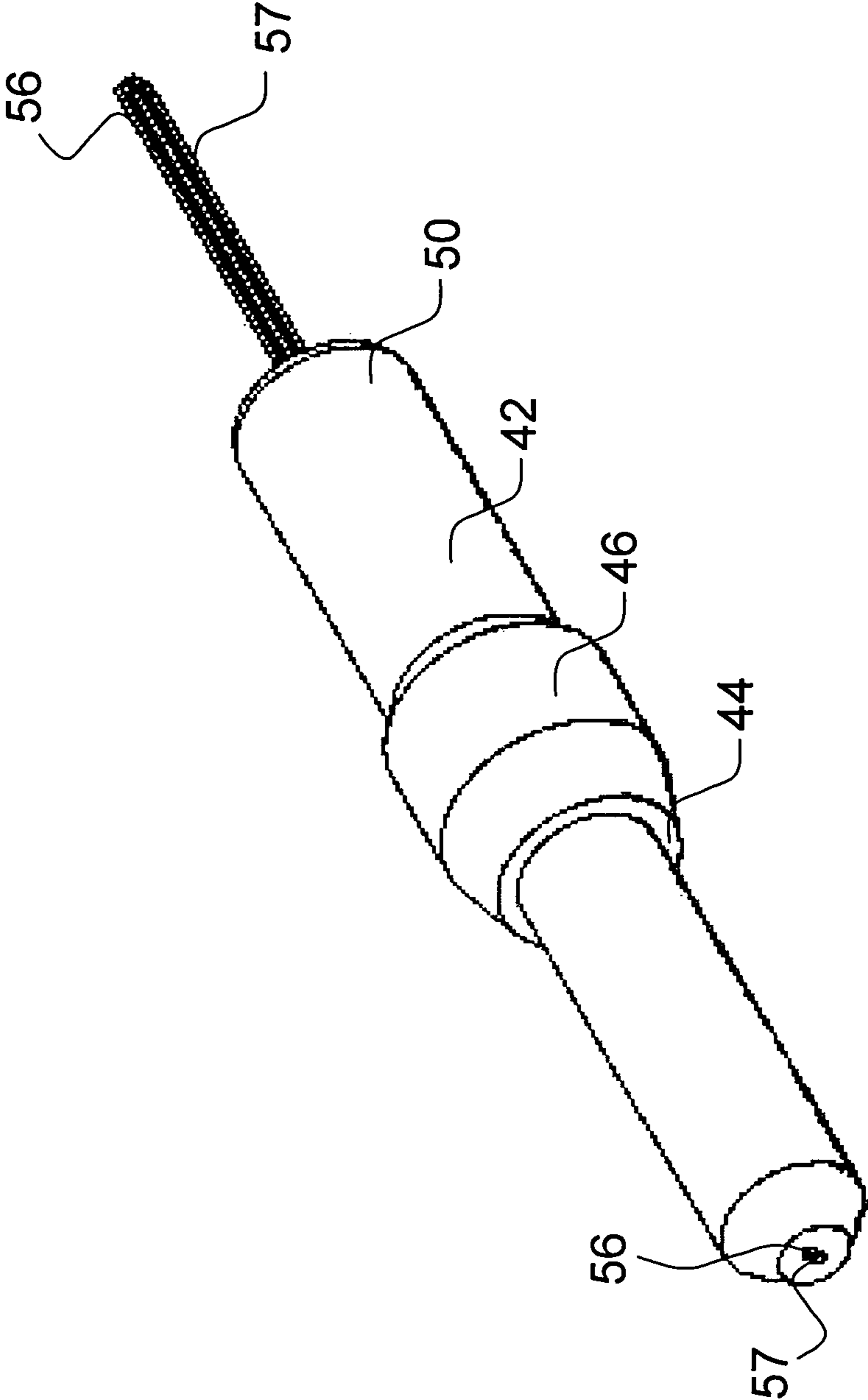


Fig. 14



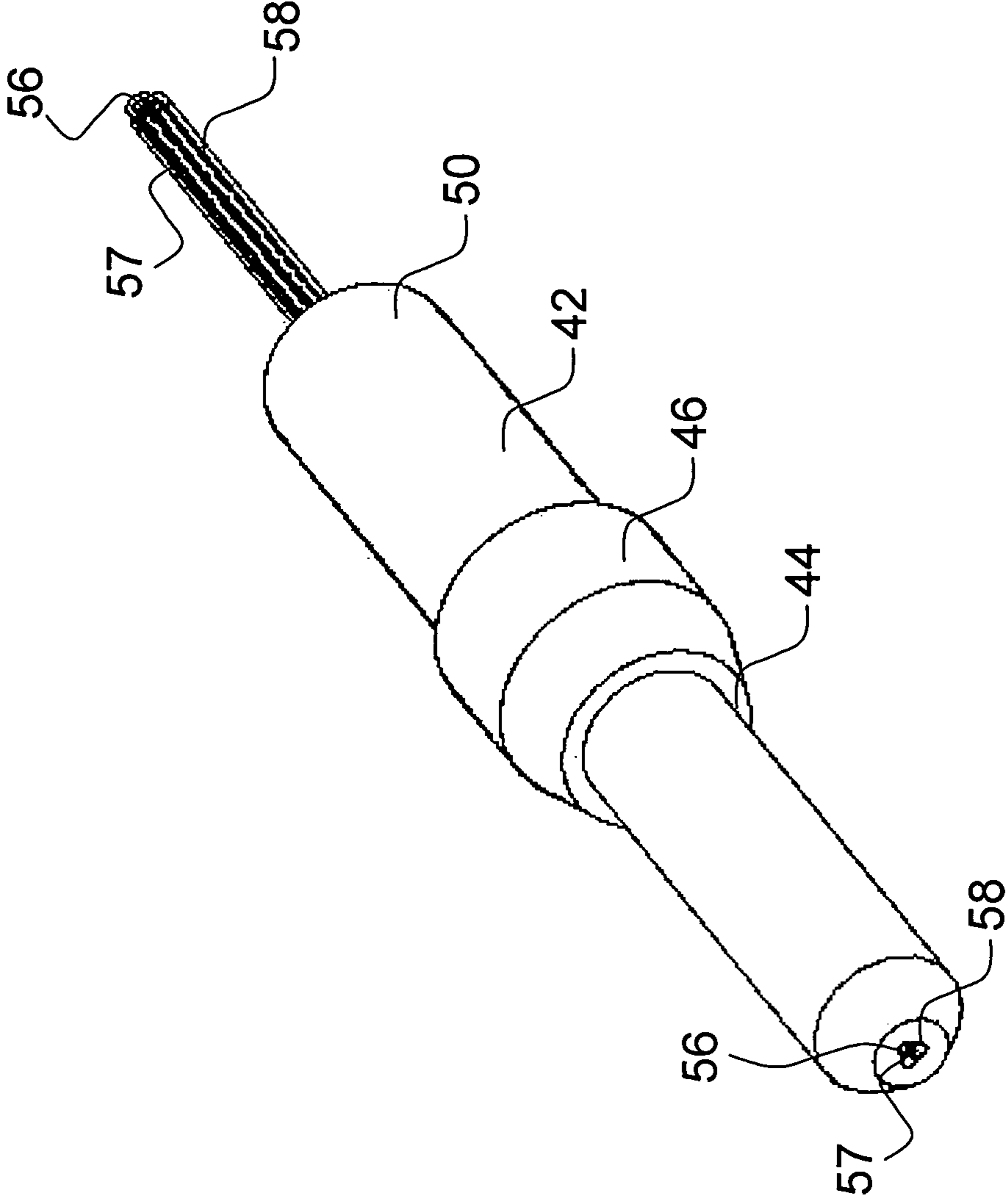


Fig. 15

# 1

## SENSOR APPARATUS

### FIELD OF THE INVENTION

The present invention relates to a sensor apparatus for detecting an object.

Such a sensor apparatus comprises a sensor head having a plurality of receiving spaces for individual sensor devices and a driving mechanism for providing a relative movement of the object relative to the sensor head in an advance direction during a detecting operation.

The invention also relates to a method for detecting an object.

In this method the object is detected by a plurality of individual sensor devices and the object is moved relative to the sensor devices in an advance direction during a detecting operation.

### RELATED ART

In a known sensor apparatus the sensor devices are arranged in a linear array or row, which extends transversely to the advance direction of the product. As the sensor devices, for example photodiodes, have certain dimensions, the resolution that can be achieved with such a sensor apparatus is limited.

### SUMMARY OF THE INVENTION

It is an object of the invention to provide a sensor apparatus and a method for detecting an object having a good resolution.

The object is solved according to the invention with a sensor apparatus and a method as described herein.

The sensor apparatus is characterized in that the receiving spaces are arranged in a plurality of rows and columns, such that an array of receiving spaces with a rectangular pattern of the receiving spaces is formed, and the array of receiving spaces is tilted with regard to the advance direction such that the rows extend in a transverse direction relative to the advance direction and the receiving spaces of a successive row of the rectangular pattern are offset with regard to the receiving spaces of a preceding row of the rectangular pattern in a direction perpendicular to the advance direction.

One basic idea of the invention is to provide a sensor head with a plurality of rows of receiving spaces for individual sensor devices in order to enhance the speed of a detecting operation as compared to a sensing head having only a single row of sensor devices. The rows, in which the receiving spaces are arranged, extend in a transverse direction, that is, they extend transversely to the advance direction.

A further basic idea of the invention is to operate all sensor devices simultaneously, while the object is moved relative to the sensor head. In case that an image is detected or scanned, the original image is produced successively with an ongoing product movement.

According to the invention, at least a part of the receiving spaces of the sensor head is arranged in a regular pattern of rows and columns, wherein the columns are perpendicular to the rows. Such a pattern is referred to as a rectangular pattern of receiving spaces. In the rectangular pattern, the receiving spaces are arranged in a manner, that in each case four receiving spaces are arranged in the edges of a rectangle. The rectangular pattern may also be referred to as an orthogonal arrangement of receiving spaces. The receiving spaces are in particular arranged in a two-dimensional array or in a matrix.

It is preferred that the receiving spaces are arranged in a regular pattern, in which the pitch of the receiving spaces, that

# 2

is the distance between two central points of neighbouring receiving spaces in one row or column, is constant. More particularly, it is preferred that a row pitch and column pitch are equal. The pitch of receiving spaces of the sensor head is also called the device pitch.

A basic aspect of the invention is to arrange the rows of receiving spaces for the sensor devices such that they extend transversely, but not perpendicularly, to the advance direction. Consequently, the columns of receiving spaces also extend transversely to the advance direction. The array of receiving spaces is thus rotated or tilted from a position, in which the columns are aligned with the advance direction, to a position, in which the columns are inclined or slanted with regard to the advance direction. As the receiving spaces are arranged in a rectangular array, the rows are also inclined or slanted with regard to a direction perpendicular to the advance direction.

It is preferred that the sensor head is a page-wide sensor head, that is, the sensor head has a width corresponding to the width of an object or image to be detected or scanned. The width of the object or image is defined as the dimension of the object or image of the transverse direction, in particular the direction perpendicular to the advance direction. The object or image may therefore be detected by moving the sensor head in the advance direction without overlaying a further movement of the sensor head in the transverse direction. The advance direction, which may also be called the product movement direction, is in particular a linear direction.

In a preferred embodiment of the sensor head, the receiving spaces are arranged in a regular field having a fundamentally rectangular shape. By tilting the rectangular field of receiving spaces relative to the advance direction, the detecting or scanning resolution may be enhanced, while at the same time an easy manufacturing of the sensor head is maintained. Each of the receiving spaces may be equipped with at least one, in particular exactly one, sensor device for detecting an object or an image on the object. The sensor devices may in particular be optical sensor devices such as for example a photodiode. Each of the sensor devices may detect or scan a single pixel or a line of pixels arranged in the product movement direction, when the object is moved relative to the sensor head.

In a preferred embodiment of the sensor apparatus a tilting angle, which is defined as the angle between the columns and the advance direction, is smaller than 45 degrees. It is preferred, that a tilting angle is in the range of 1 to 10 degrees, more preferably 2 to 8 degrees, even more preferably 2 to 5 degrees. In conjunction with an array of 32 times 32 receiving spaces the tilting angle is preferably about 2.7 degrees. The tilting of the array of receiving spaces may be achieved by tilting the sensor head relative to the advance direction and/or by tilting the array relative to the sensor head.

In a preferred embodiment of the invention, the receiving spaces are arranged in a regular rectangular pattern and the amount of offset of the receiving spaces of a successive row with regard to the receiving spaces of a preceding row is smaller than a pitch of receiving spaces of one row. The amount of offset is in particular the distance in a direction perpendicular to the advance direction between two corresponding receiving spaces of neighbouring or adjoining rows. The amount of offset corresponds to a scan line pitch.

In other words, a scan line pitch, that is a pitch of the scan lines or pixels in a direction perpendicular to the advance direction, is preferably smaller than the device pitch of one row, that is the pitch of the receiving spaces/sensor devices of one row. The columns of the array of receiving spaces are inclined such that the successive sensor device of one column

scans a pixel that is offset with regard to the advance direction compared to a pixel scanned by a preceding sensor device of the same column.

In the regular rectangular pattern the pitch of receiving spaces of one row is preferably constant. In a preferred embodiment, which results in the maximum possible resolution, the amount of offset is defined as the reciprocal value of the number of rows.

In another preferred embodiment the rectangular pattern of rows and columns is tilted to a degree, in which at least a part of the receiving spaces of at least one row of the rectangular pattern is aligned with at least a part of the receiving spaces of at least one preceding row in the advance direction.

With this embodiment, a multiple scan of one the same pixel to be scanned is possible. That is, one and the same pixel may be scanned or detected by multiple sensor devices. The receiving spaces aligned in the advance direction preferably constitute receiving spaces of directly adjacent columns.

With the possibility of reading the same pixel with multiple sensors, it is for example possible to read different colours. For instance, three sensor devices for three different colours may be arranged in the array of receiving spaces such that they are aligned in the product movement direction.

The scanning resolution may be adjusted in that the sensor head is rotatable about an axis perpendicular to the advance direction such that the amount of offset of the receiving spaces is adjustable. In particular, the sensor head is rotatable about an axis being perpendicular to a surface of the object to be scanned. Alternatively or additionally, it is also possible to rotate the array of receiving spaces/sensor devices within the sensor head.

For a movement of the sensor head it is preferred that a motor, in particular a stepper motor, is provided for rotating the sensor head, in particular at defined small angle steps in the range of 0 to 90 degrees. The motor may in particular be an electrical motor.

Generally, receiving spaces of the sensor head may be equipped with individual sensor devices. For a flexible adjustment of the sensor head to a specific scanning or a detecting operation, it may be preferable that—besides the possibility of entirely filling the receiving spaces with sensor devices—the receiving spaces are configured to be partially equipped with sensor devices. In this regard, the sensor head is operable with an only partially filled array of receiving spaces.

In a preferred embodiment at least a part of the receiving spaces is equipped with sensor devices, wherein the sensor devices comprise at least an optical sensor element, a capacity sensor element, an inductive sensor element and/or a chemical sensor element. The sensor devices may for example be optical sensors, temperature sensors or infrared sensors. With a temperature or infrared sensor, a surface temperature profile of the object to be scanned can be detected. The sensor devices may be configured to detect a colour profile or a coating thickness profile of the object.

The sensor devices may for example comprise a PIN diode, a photodiode or a phototransistor. It is also possible to use pyroelectric sensor devices or micro antennae as sensor devices.

In another preferred embodiment of the invention at least a part of the receiving spaces is equipped with optical sensor devices, wherein the optical sensor devices comprise a fibre, which is arranged in a ferrule.

It is therefore a preferred embodiment of the invention that the sensor head comprises a plurality of ferrules arranged in a two-dimensional array. The fibres arranged in the ferrules may be coupled to a sensor element for detecting a light signal received from the object.

A reliable light signal may be achieved in that a lighting element, in particular a light emitting diode (LED), is arranged within the ferrule. The lighting element may be used for illuminating the object. The light of the lighting element is reflected or scattered by the object and is detectable by a sensor element arranged at an end of the fibre.

In another preferred embodiment a sensor element, in particular a sensor diode such as a photodiode, is arranged within the ferrule. In this case, the fibre of the ferrule may be coupled to a lighting element, for example a light emitting diode, for illuminating the object. The light is reflected or scattered by the object and detected by the sensor element arranged in the ferrule.

In particular in the case that the ferrule comprises a sensor element and/or a lighting element, it is preferred that the ferrule is at least partly transparent.

In a preferred embodiment of the sensor head, the sensor head comprises a receiving plate with a plurality of receiving holes as receiving spaces. The sensor devices, for example individual ferrules with fibre ends or individual photodiodes, may be placed and fixed in the receiving spaces. It is particularly preferred that the receiving holes are through-holes, into which the sensor devices may be inserted.

In a preferred embodiment, at least a part of the receiving holes has a circular cross-section. The circular cross-section allows for a good and tight connection of individual fibre ferrules. In this regard, it is preferred that the ferrules have a circular outer shape corresponding to the circular cross-section of the receiving holes.

The ferrules may fit into the holes in medium or transition fit, such that it is possible that the ferrules may be placed in the receiving holes and removed thereof by using a simple hand tool. It is particularly preferred that no additional fixtures are needed to bond the ferrules into the holes.

For holding the ferrules tight and removable in the receiving holes, it is preferred that a capture pad is arranged at at least one surface of the receiving plate. It is preferred that the capture pad includes an elastic polymer, in particular a rubber and/or an elastomer. The capture pad is preferably made of Viton® (a trademark belonging to E.I. DuPont de Nemours & Co. of Delaware) or includes the material Viton®. The ferrules may be pushed through the capture pad and are then held in place by the capture pad as it closes the ferrule after insertion. The ferrules can be removed by pushing back through from one side of the receiving plate.

In a further preferred embodiment a lens array comprising a plurality of lenses is provided, wherein the lenses are arranged in a rectangular pattern of rows and columns corresponding to the rectangular pattern of rows and columns of the receiving spaces. The lens array may be formed as a single unit or as individual lens inserts to be coupled to the receiving spaces of the sensor head.

It is also possible to arrange a single lens instead or in addition to the lens array. In another preferred embodiment, individual lenses may be inserted into the receiving holes of the receiving plate.

An inventive method is characterized in that the sensor devices are arranged in a plurality of rows and columns, such that an array of sensor devices with a rectangular pattern of the sensor devices is formed, and the object is detected or scanned while the array of sensor devices is tilted with regard to the advance direction such that the rows extend in a transverse direction relative to the advance direction and the sensor devices of a successive row of the rectangular pattern are offset with regard to the sensor devices of a preceding row of the rectangular pattern in a direction perpendicular to the advance direction.

## 5

With an inventive method, the advantages discussed in connection with the sensor apparatus may be achieved. In particular, it is possible to achieve a high resolution in a detecting or scanning operation.

## BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be further described with reference to the attached figures, wherein:

FIG. 1 shows an inventive sensor apparatus;

FIG. 2 shows a perspective view of an inventive sensor head;

FIG. 3 shows the general principle of the inventive sensor apparatus and method;

FIG. 4 shows an array of receiving spaces for sensor devices;

FIG. 5 shows a fully populated and tilted array;

FIG. 6 shows the general principle of a multiple scan option;

FIG. 7 shows a CCD or CMOS device as sensor devices;

FIG. 8 shows a cross-sectional view of a first embodiment of a sensor device array;

FIG. 9 shows a cross-sectional view of a second embodiment of a sensor device array;

FIG. 10 shows a cross-sectional view of a third embodiment of a sensor device array;

FIG. 11 shows a cross-sectional view of a fourth embodiment of a sensor device array;

FIG. 12 shows a cross-sectional view of a fifth embodiment of a sensor device array;

FIG. 13 shows a cross-sectional view of a sensor head with a motor;

FIG. 14 shows a perspective view of a ferrule with two fibres; and

FIG. 15 shows a perspective view of a ferrule with three fibres.

## DETAILED DESCRIPTION OF THE INVENTION

The principle structure of an inventive sensor apparatus 10 is shown in FIG. 1. The sensor apparatus 10 comprises a sensor device control and driving unit 12 and a sensor head 20 that is connected to the sensor device control and driving unit 12 through an umbilical 14. The sensor apparatus 10 may in particular be a pixel or matrix sensor apparatus.

FIG. 2 shows a general structure of a sensor head 20. The sensor head 20 comprises a housing 21, which in the shown embodiment has a cylindrical outer shape. At a first front face of the cylindrical sensor head 20 a plurality of receiving spaces 24 is arranged in a regular rectangular pattern. The receiving spaces 24 are populated with individual sensor devices 50, which may in particular be photodiodes or fibre ends coupled to photodiodes.

The rectangular pattern of receiving spaces 24 and sensor devices 50, respectively, forms a two-dimensional array 22, in particular with a rectangular outer shape. In the two-dimensional array 22 the receiving spaces 24 and sensor devices 50, respectively, are arranged in rows 30 and columns 32 extending perpendicularly to each other.

The general principle of a detecting or scanning operation is shown in FIG. 3. The sensor head 20 is arranged in a tilted or inclined position with regard to an advance direction 16 of an object 8 to be scanned. In particular, in the tilted or inclined position of the sensor head 20 the receiving spaces 24 of different rows 30 are offset with regard to the advance direction 16. The receiving spaces 24 are equipped with individual sensor devices 50.

## 6

The sensor devices 50 of a first row 30a are arranged to scan the object 8 along first individual lines 6a parallel to the advance direction 16 when the object is moved in the advance direction 16. The first lines 6a are spaced from one another in a direction perpendicular to the advance direction 16. A second row 30b is offset with regard to the first row 30a such that the sensor devices 50 of the second row 30b are arranged to scan the object 8 along second individual lines 6b spaced from one another and spaced from the first individual lines 6a in a direction perpendicular to the advance direction 16. The sensor devices 50 of a last row 30c are arranged to scan the object 8 along individual lines 6c spaced from one another and spaced from all preceding lines 6a, 6b in a direction perpendicular to the advance direction 16.

An array 22 of receiving spaces 24 of a sensor head 20 is shown in FIG. 4. The receiving spaces 24 are formed in a receiving plate 28, which may be a metal plate, for example a steel plate, for example with a thickness of approximately 5 mm. The receiving spaces 24 are formed as circular receiving holes 26 in the receiving plate 28, in particular through-holes with a circular cross-section.

In a preferred embodiment the array 22 of receiving spaces 24 has a device pitch 34 in the row direction and in the column direction of about 1 to 4 mm, the device pitch 34 being defined as the distance between the central points of two adjacent receiving spaces 24 in one row 30 or column 32, respectively. It is preferred that each of the receiving holes 26 has a diameter 27 of 1 to 3 mm.

In the shown embodiment, the receiving plate 28 comprises an array 22 of receiving spaces 24 arranged in a regular square pattern. The shown array 22 comprises 32 times 32 receiving spaces 24 with a device pitch 34 of 3.2 mm and a diameter 27 of the receiving spaces 24 of 2.0 mm, resulting in a width 29 of the array 22 in the row and column direction of 102.4 mm.

In addition to the array 22 of receiving spaces 24, a plurality of spare receiving spaces 25 is provided for accommodating spare sensor devices 51. The spare receiving spaces 25 are also formed as receiving holes in the receiving plate 28.

In FIG. 5 a fully populated receiving plate 28 is shown in a tilted position. The tilted position is defined in particular in that the rectangular pattern of rows 30 and columns 32 is tilted from a position in which the columns 32 are aligned with the advance direction 16 to a position in which the columns 32 are slanted or inclined with regard to the advance direction 16.

The tilted or inclined position of the array 22 enhances the maximum possible resolution of the scanning. A first row 30a of sensor devices 50 may scan the object with a resolution in the transverse direction according to the number of sensor devices 50 in the first row 30a. That is, if the first row 30a comprises 32 sensor devices 50, the maximum resolution in the transverse direction is 32 lines or pixels. Due to the tilted position of the array, a second row 30b is staggered with regard to the first row 30a in the transverse direction, so that the sensor devices 50 of the second row 30b may scan lines, which are offset with regard to the lines of the first row 30a. Thus, the resolution of the scanning is doubled, if the first and second rows have the same number of sensor devices 50.

A third row and successive rows 30 are also staggered with regard to any of the preceding rows 30, so that the resolution is further enhanced. The maximum possible resolution is defined by the product of the number of sensor devices 50 per row and the number of sensor devices 50 per column. For example, if the sensor head 20 has 32 times 32 sensor devices 50 arranged in a slanted or inclined array 22, the maximum resolution is 1024 pixels in the transverse direction, in particular a direction perpendicular to the advance direction 16.

With the tilted array **22** of sensor devices **50** a scanning line pitch **35** being a distance between two adjacent scanning lines is smaller than the device pitch **34**.

FIG. **6** schematically shows different tilting angles **38** (cf. FIG. **5**) of a sensor device array **22**. In the left representation of FIG. **6** the array **22** is tilted to a degree such that each of the sensor devices **50** of one column **32** is arranged to scan the object **8** along line **6** that is offset with regard to any of the lines being scanned by any of the other sensor devices **50** of the same column **32** when the object **8** is moved along the advance direction **16**. That is, the sensor devices **50** of one column **32** are offset with regard to any other sensor devices **50** of the same column **32**. With this configuration the maximum resolution of a given sensor head **20** may be achieved.

In the middle representation the array **22** is tilted to a degree in which a double scan of any pixel is possible. That is, the sensor devices **50** of one column **32** correspond to the sensor devices **50** of another column **32** such that one and the same pixel may be scanned by two different sensor devices **50** arranged in different columns **32**.

In the right representation the array **22** is tilted to a degree in which a triple scan of any pixel is possible. That is, the sensor devices **50** of one column **32** correspond to the sensor devices **50** of two other columns **32** such that one and the same pixel may be scanned by three different sensor devices **50** arranged in different columns **32**.

FIG. **7** shows an array **22** of sensor devices **50**, wherein the sensor devices **50** are formed in a CCD device or CMOS device. The sides of the array **22** are cut such that a tilted array **22** is achieved, as shown in FIG. **7**.

The array **22** of receiving spaces **24** and sensor devices **50**, respectively, does not necessarily have to be a two-dimensional array **22**. The receiving spaces **24** and sensor devices **50**, respectively, can also be arranged in a curved surface. Such three-dimensional structures may for example be used for scanning bottles or similar objects. A closed three-dimensional structure may for example be used for scanning a cylindrical product.

FIG. **8** shows a cross-sectional view of a receiving plate **28** with receiving spaces **24**, in which sensor devices **50** are arranged. The receiving spaces **24** are formed as receiving holes **26**, in particular through-holes. The sensor devices **50** each comprise a fibre-ferrule **42**, in which a fibre end of a fibre **56** is arranged. The ferrules **42** are mounted into the receiving holes **26**.

FIGS. **8** and **9** also show a capture pad **70** arranged at at least one surface of the receiving plate **28**, for holding the ferrules **42** tight and removable in the receiving holes **24**.

FIG. **9** shows a sensor head **20** with a lens array **60**. The lens array **60** has the same pitch as the array **22** of receiving spaces **24**.

A sensor head **20** with individual lenses or lens inserts **62** inserted into receiving holes **26** of a receiving plate **28** is shown in FIG. **10**. With the individual lenses **62**, different focal distances for non-planar objects to be scanned are possible. It is also possible to use mixed scanning technologies.

FIG. **11** shows a cross-sectional view of a receiving plate **28** having a plurality of receiving holes **26**, which are arranged in a two-dimensional matrix. The receiving holes **26** are equipped with individual sensor devices **50**, the sensor devices **50** including a ferrule **42** with a channel formed therein. A fibre **56** is coupled to the ferrule **42** such that a fibre end is fixed in the channel of the ferrule **42**.

The fibre **56** is connectable to a sensor element for detecting a light signal. The sensor element may for example be a photodiode.

The ferrule **42** includes a lighting element **52** for emitting a light signal onto the object **8**. The lighting element **52** is imbedded in a housing of the ferrule **42**. The lighting element **52** may have a ring-shape such that the fibre **56** may pass through the lighting element **52** and the lighting element **52** is arranged around the fibre **56**. For illuminating the object **8** the ferrule **42** is at least partly transparent.

FIG. **12** shows a cross-sectional view of a receiving plate **28** with receiving holes **26**, wherein the ferrules **42** arranged therein comprise a sensor element **54** such as a photodiode for detecting a light signal of the object **8**. The sensor element **54** is imbedded in a housing of the ferrule **42**. The sensor element **54** may have a circular shape such that the fibre **56** of the ferrule **42** may pass through the sensor element **54**. The object **8** may be illuminate through the fibres **56**.

In the cases that a lighting element **52** or a sensor element **54** is arranged in the ferrules **42** it is preferable that a lens **62** is arranged between the ferrule **42** and the object **8**. A plurality of lenses **62** may form a lens array **60**, as shown in FIGS. **11** and **12**.

A rotatable sensor head **20** is shown in FIG. **13**. The sensor head **20** comprises a receiving plate **28** with receiving spaces **24** formed therein. A motor **64**, in particular a stepper motor, is arranged for rotating the sensor head **20** and/or the receiving plate **28**. A transmission **66**, which in the shown embodiment is a belt, is arranged between an output shaft of the motor **64** and the sensor head **20**. The sensor head **20** may in particular have a cylindrical outer shape.

A perspective view of a fibre-ferrule **42** is shown in FIG. **14**. The fibre-ferrule **42** includes a substantially cylindrical body or insert made of metal—preferably steel—, ceramic, plastic or glass. It is preferred that the ferrule **42** includes zirconia. The cylindrical body includes a collar **46** with an abutment surface **44** for contacting a planar surface of the receiving plate **28**.

The ferrule **42** may have one or more fibres **56** arranged therein. FIG. **14** shows an embodiment with two fibres **56**, **57**. One of the fibres **56**, **57** may be used for illumination, that is, illuminating the object **8** to be detected, and the other fibre may be coupled to a sensor element. The multiple fibre-ferrules **42** can also be used as online pixel monitor. Failed pixels can be recognized during run time. If the fibres **56**, **57** of the ferrule **42** are each monitored individually, that is, each fibre is connected to a sensor element, a reliable sensor device **50** can be provided. This sensor device **50** includes a fibre break monitor. There may be no need for a ferrule **42** with a mirror in front.

A ferrule **42** with three fibres **56**, **57**, **58** is shown in FIG. **15**. Such a ferrule **42** may for example be used for colour imaging. The three fibres **56**, **57**, **58** can form an RGB-grouping. Connecting the fibres **56**, **57**, **58** to sensor elements would allow for colour imaging where the RGB-configuration is used. The sensor elements can be filtered for the appropriate colour.

Generally, the fibre diameters could be increased in size to fill a major portion of the ferrule cross-section to increase signal sensitivity.

The invention claimed is:

1. A sensor apparatus for detecting an object, comprising:
  - a sensor head having a plurality of receiving spaces for individual sensor devices and
  - a driving mechanism for providing a relative movement of the object relative to the sensor head in an advance direction during a detecting operation,
 wherein the receiving spaces are arranged in a plurality of rows and columns, such that an array of receiving spaces is formed, and

9

wherein the array of receiving spaces is tilted with regard to the advance direction such that the rows extend in a transverse direction relative to the advance direction and the receiving spaces of a successive row of the rectangular pattern are offset with regard to the receiving spaces of a preceding row of the rectangular pattern in a direction perpendicular to the advance direction,

wherein

the array of the receiving spaces has a rectangular pattern,

the sensor head comprises a receiving plate having a plurality of receiving holes formed as through-holes therein, the receiving holes forming the receiving spaces for the individual sensor devices,

the sensor devices each include a ferrule which is inserted into a receiving hole of the receiving plate, the receiving holes are formed to tightly and removably hold the individual ferrules therein, and a capture pad is arranged at at least one surface of the receiving plate for holding the sensor devices tight and removable.

2. The sensor apparatus of claim 1, wherein the receiving spaces are arranged in a regular rectangular pattern and the amount of offset of the receiving spaces of a successive row with regard to the receiving spaces of a preceding row is smaller than a pitch of the receiving spaces of one row.

3. The sensor apparatus of claim 1, wherein the rectangular pattern of rows and columns is tilted to a degree in which at least a part of the receiving spaces of at least one row of the rectangular pattern is aligned with at least a part of the receiving spaces of at least one preceding row in the advance direction.

4. The sensor apparatus of claim 1, wherein the sensor head is rotatable about an axis perpendicular to the advance direction such that the amount of offset of the receiving spaces is adjustable.

5. The sensor apparatus of claim 1, wherein a motor is provided for rotating the sensor head.

6. The sensor apparatus of claim 1, wherein the receiving spaces are configured to be partially equipped with sensor devices.

7. The sensor apparatus of claim 1, wherein at least a part of the receiving spaces is equipped with sensor devices, wherein the sensor devices comprise at least one of:

an optical sensor element, a capacity sensor element, an inductive sensor element and a chemical sensor element.

8. The sensor apparatus of claim 1, wherein at least a part of the receiving spaces is equipped with optical sensor devices, wherein the optical sensor devices comprise a fibre, which is arranged in a ferrule.

9. The sensor apparatus of claim 8, wherein a lighting element is arranged within the ferrule.

10. The sensor apparatus of claim 8, wherein a sensor element is arranged within the ferrule.

10

11. The sensor apparatus of claim 8, wherein the ferrule is at least partly transparent.

12. The sensor apparatus of claim 1, wherein at least a part of the receiving holes has a circular cross-section.

13. The sensor apparatus of claim 1, wherein the ferrules fit into the receiving holes in medium or transition fit.

14. Method for detecting an object, with the sensor apparatus of claim 1, wherein

the object is detected by a plurality of individual sensor devices,

the object is moved relative to the sensor devices in an advance direction during a detecting operation,

the sensor devices are arranged in a plurality of rows and columns, such that an array of sensor devices with a rectangular pattern of the sensor devices is formed, and the object is detected while the array of sensor devices is tilted with regard to the advance direction such that the rows extend in a transverse direction relative to the advance direction and the sensor devices of a successive row of the rectangular pattern are offset with regard to the sensor devices of a preceding row of the rectangular pattern in a direction perpendicular to the advance direction.

15. A sensor apparatus for detecting an object, comprising: a sensor head having a plurality of receiving spaces for individual sensor devices and

a driving mechanism for providing a relative movement of the object relative to the sensor head in an advance direction during a detecting operation,

wherein the receiving spaces are arranged in a plurality of rows and columns, such that an array of receiving spaces is formed, and

wherein the array of receiving spaces is tilted with regard to the advance direction such that the rows extend in a transverse direction relative to the advance direction and the receiving spaces of a successive row of the rectangular pattern are offset with regard to the receiving spaces of a preceding row of the rectangular pattern in a direction perpendicular to the advance direction,

wherein

the array of the receiving spaces has a rectangular pattern,

the sensor head comprises a receiving plate having a plurality of receiving holes formed as through-holes therein, the receiving holes forming the receiving spaces for the individual sensor devices,

the sensor devices each include a ferrule which is inserted into a receiving hole of the receiving plate, a lighting element is arranged within the ferrule, and the receiving holes are formed to tightly and removably hold the individual ferrules therein,

wherein either a sensor element is arranged within the ferrule, or the ferrule is at least partly transparent.

\* \* \* \* \*